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Report No. FAA-AVP-77-4

Estimation of UG3RD Productivity Impacts

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January 1977
FINAL REPORT

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Office of Aviation Policy
Washington, D.C. 20591

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
14 FAA-AVP-77-4		

4. Title and Subtitle	5. Report Date
6 Estimation of UG3RD Productivity Impacts.	11 Jan[illegible] 1977 12 58p.
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s) 10 John M./Rodgers	
9. Performing Organization Name and Address Office of Aviation Policy Federal Aviation Administration U.S. Department of Transportation Washington, D.C. 20591	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Same	13. Type of Report and Period Covered 9 Final Report.,
	14. Sponsoring Agency Code

15. Supplementary Notes

This document presents a synthesis of research results on air traffic control productivity performed under FAA research contracts with Stanford Research Institute and METIS Corporation.

16. Abstract

This study estimates the value of savings attainable from reduced Air Traffic Service staff requirements associated with implementation of the Upgraded Third Generation Air Traffic Control System (UG3RD). Estimates of staff requirements, assuming either a continuation of the present air traffic control system or alternatively, various UG3RD improvements, were prepared from an analysis of specific job functions at sample facilities. Sample estimates were expanded to provide estimates of required staff at all centers and 30 selected TRACONS and/or terminals for the period 1976 and 2000. Manpower differentials were calculated and valued at an average 1975 wage plus benefit cost.

17. Key Words	18. Distribution Statement
Air Traffic Control Productivity Upgraded Third Generation Air Traffic Control System FAA Controller Staff Requirements	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	51	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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ACKNOWLEDGMENTS

Estimates of potential controller staff savings associated with the Upgraded Third Generation Air Traffic Control System (UG3RD) presented in this report are based on research conducted by Stanford Research Institute and Metis Corporation sponsored by the Office of Aviation Policy. Productivity impacts of the UG3RD at enroute centers were studied by G.T. Couluris and are documented in Case Study of the Upgraded Third Generation Enroute ATC Staffing Requirements for the Los Angeles Center [6]. An analysis of UG3RD impacts on terminal staff requirements was conducted by Metis Corporation and is contained in ARTS III Enhancement Costs and Benefits [11] In addition, G.T. Couluris and J.M. Johnson integrated terminal and enroute staffing impacts in First-Cut Comparative Cost Estimates of Productivity of UG3RD ATC Alternatives [5]. Staff saving estimates from these sources have been integrated in the present document and are incorporated in Policy Analysis of the UG3RD ATC System [9].

EXECUTIVE SUMMARY

This study estimates the value of savings attainable from reduced Air Traffic Service staff requirements associated with implementation of the Upgraded Third Generation Air Traffic Control System (UG3RD). Study results serve as an input to a system cost-benefit analysis of the UG3RD [9].

Five alternative configurations of components were evaluated by the system cost-benefit analysis. These configurations can be categorized into two groups according to anticipated productivity impacts. Configuration 1 achieves reduced staff requirements through automated data distribution and a basic metering and spacing feature. Configurations 2 through 5 include data distribution, conflict resolution, control message automation, and a Discrete Address Beacon System (DABS) with data link. Staff savings are achieved by changing the controller's role to that of a system manager. Differences in productivity impacts of Configurations 2 through 5 result from the degree to which DABS (data link) is implemented.

Estimates of staffing requirements assuming either a continuation of the present air traffic control system or alternatively, various UG3RD improvements, were prepared from an analysis of specific job functions at sample facilities. Sample facility staffing requirements were expanded to provide estimates of required staff at all centers and 30 selected TRACONS and/or terminals for the period 1976 through 2000. Manpower differentials between a situation of no change in the ATC system and the various UG3RD configurations were calculated and valued at an average 1975 wage plus benefit-cost.

Each of the five configurations provide significant potential savings due to reduced personnel costs. Estimated savings for the period 1976-2000 are as follows:

Configuration 1	- $4.1 billion
Configurations 2 and 4	- $4.7 billion
Configurations 3 and 5	- $5.3 billion

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1.0 Introduction

A system cost-benefit study of proposed investment in the Upgraded Third Generation Air Traffic Control (UG3RD) has been conducted by the Federal Aviation Administration (FAA) with the assistance of several independent research organisations. Findings are documented in Policy Analysis of the UG3RD ATC System [9].

Cost and benefits of implementing alternative UG3RD systems are estimated vis a vis continuation of the present air traffic control system. The analysis valued the costs and benefits of five alternative UG3RD systems composed of potential combinations of UG3RD components. Alternative UG3RD configurations selected for evaluation consisted of component combinations which produce system interaction and bound the range of potential program costs and types of benefits. For each alternative UG3RD configuration, the added cost of airport and airway services associated with UG3RD implementation was quantified for both the Federal Aviation Administration and for airway system users. Costs were compared with the value of potential improvements in the airport and airway system. Benefits consisted of increased airport capacity and reduced delay, savings from reduced FAA staff requirements, and improved airway system safety.

System cost-benefit findings are based on analyses supplied by several research organizations. The MITRE Corporation evaluated the impact of various potential UG3RD configurations on airport capacity and aviation safety [18 and 20]. Battelle Columbus Laboratories translated UG3RD impacts on airport capacity into estimates of changes in aircraft and passenger delay [17]. Labor productivity impacts are based on research conducted at Stanford Research Institute [5] and Administrative Science Corporation [1]. Cost estimates and assessment of energy and environments impact of the UG3RD were the responsibility of the Transportation Systems Center (TSC).

The present document presents estimates of savings from reduced FAA controller staff requirements and describes estimation procedures.

1.1 Objective of the Study

The objective of the present study was to estimate future levels of Air Traffic Service staff that will be required at enroute centers and selected terminals assuming a continuation of the present air traffic control system and alternatively, assuming implementation of various potential configurations of the UG3RD. Estimates of the impact of the UG3RD on controller staff requirements and associated savings are needed as inputs to the UG3RD system cost-benefit analysis [9] and were specifically requested by the Office of the Secretary of Transportation (OST) as part of its Review of Upgraded Third Generation Air Traffic Control System [14]. Specifically, OST requested that the FAA conduct analyses to confirm or revise assumptions regarding the expected effect of the UG3RD on productivity and incorporate these results into a cost-benefit analysis of UG3RD automation improvements. The present study is intended to fulfill the intent of the OST directive in the context of providing productivity impact estimates for an analysis of UG3RD costs and benefits from a system perspective.

1.2 Approach

Potential increases in controller productivity (increased ratios of operations per controller while maintaining or improving the quality of service) associated with various ATC improvements have been estimated by Stanford Research Institute (SRI) [5] and Metis Corporation [11]. Estimates of controller staff savings associated with alternative configurations of the UG3RD are based on the SRI-Metis results.

First, estimates of staffing requirements assuming either a continuation of the present air traffic control system or alternatively, various UG3RD improvements, were prepared from an analysis of specific job functions at sample facilities. Enroute center impacts are based on an analysis of the Los Angeles ARTCC while terminal impacts were based on studies of the Atlanta, Boston, Washington National and Jacksonville terminals. Next, sample facility annual staffing requirements were expanded to provide estimates of required staff at all centers and at 30 selected TRACONS and/or terminals (see Table 2.2). At this stage, annual estimates were prepared for centers, but terminal staff estimates were prepared at five year intervals for the period 1975 through 2000.

Terminal staff requirements at five year intervals were interpolated to obtain annual staff requirements. Finally, manpower differentials between a situation of no change in the ATC system and various UG3RD configurations were calculated and valued at a 1975 average wage of $24,795 [22] to estimate the value of potential controller staff savings.

1.3 Organization of the Report

The remainder of this report is organized to discuss potential UG3RD system configurations and their relationships to productivity in Chapter 2. Estimates of staff savings at enroute centers are presented in Chapter 3. In Chapter 4, similar estimates are developed for 30 terminals. Major conclusions regarding UG3RD productivity impacts are given in Chapter 5.

2.0 UG3RD System Improvements and Their Relationship to Staff Requirements

This chapter, first describes five alternative configurations of UG3RD equipment evaluated by the UG3RD system cost-benefit analysis [9] and discusses the rationale behind their selection. Second, the probable effect of the various configurations on air traffic control staff requirements is discussed in terms of the function of individual components contained in each configuration.

2.1 System Configurations

There are nine potential components which could be used to develop a UG3RD system:

1. Wake Vortex Avoidance System (WVAS)
2. Discrete Address Beacon System (DABS)
3. Intermittent Positive Control (IPC)
4. Upgraded Air Traffic Control Automation
5. Airport Surface Traffic Control (ASTC)
6. Microwave Landing System (MLS)
7. Area Navigation (RNAV)
8. Flight Service Stations (FSS)
9. Aeronautical Satellites (AEROSAT)

Descriptions of these items are provided in Appendix A.

With nine components from which to form combinations, there are numerous possible alternative UG3RD configurations. In conducting the UG3RD system cost-benefit analysis [9], a decision was therefore made to select a limited number of configurations for analysis. Candidates for inclusion in the system cost-benefit analysis were evaluated from several perspectives. First, configurations should provide benefits which are truely the products of an integrated system rather than simple aggregations of improvements obtainable from independent implementation of components. The combinations finally selected focused on benefits in the areas of capacity improvement, delay reduction, controller staff savings, safety improvements and energy and environmental impacts. A second criteria used to establish alternative configurations for the UG3RD system cost-benefit analysis was that the configurations

should bound the range of possible system costs. Further, all systems had to be technically feasible and should indicate the sensitivity of UG3RD costs and benefits to the scope of program implementation.

Using these guides, the alternatives were distilled into five technically feasible UG3RD equipment configurations. The configurations studied in the UG3RD system cost-benefit analysis are presented in Table 2.1. Further detail on siting assumptions for each configuration is provided in Table 2.2. Certain potential UG3RD components were excluded from these configurations because benefits obtainable from the components did not vary as a function of other elements included in the system. Excluded elements consisted of the microwave landing system, flight service stations, area navigation, airport surface traffic control, and aeronautical ocean satellites. The costs and benefits of systems containing these items can be estimated by adding costs and benefits associated with the individual items to those of the systems listed in Table 2.1.

Assumptions concerning the dates of full system operational capability are given in Table 2.3. These dates reflect both an assessment of the current rate of progress in technical development [and] and system financial planning considerations.

2.2 Productivity Impacts

The five configurations evaluated by the UG3RD system cost-benefit analysis (see Table 2.1) may be divided into three groups according to the anticipated productivity impacts associated with system implementation--Configuration 1, Configurations 2 and 4, and Configurations 3 and 5. 1/ The nature of changes in staff requirements are discussed below for the various configurations in terms of the effect of individual components contained in each configuration.

2.2.1 Configuration 1

Components effecting staffing requirements are confined to upgraded air traffic control automation.

1/ With the possible exception of RNAV, UG3RD components excluded from these five configurations--microwave landing systems, flight service stations, airport surface traffic control, and aeronautical satellites--are not expected to change controller staff requirements [5].

TABLE 2.1
ALTERNATIVE UG3RD SYSTEM CONFIGURATIONS
EVALUATED BY SYSTEM COST BENEFIT ANALYSIS

Configuration Number	Component Composition	Siting Assumotions	Remarks on Selection
1	WVAS – Manual Automation – Basic *Metering & Spacing,* Data Distribution	Top 30 air carrier terminals All enroute centers	Most basic synergistic system with potential *benefits of increased* airport and airway capacity and some increase in controller productivity.
2	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS	Top 30 air carrier terminals All enroute centers DABS at 100 sites	System embodies the highest envisioned level of airport and airway capacity improvement, major increases in controller productivity, and possible safety effects.
3	WVAS – Automated Automation – Advanced metering & spacing, data distribution, *conflict resolution,* control messages DABS	Top 30 air carrier terminals All enroute centers DABS at 300 sites	Same as configuration 2 except *wider DABS coverage is provided*
4	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS, IPC	Top 30 air carrier terminals All enroute centers DABS & IPC at 100 sites	System embodies the highest envisioned level of airport and airway capacity improvement, increases in controller productivity and significant collision *avoidance* benefits.
5	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS, IPC	Top 30 air carrier terminals *All enroute centers* DABS & IPC at 300 sites	Same as configuration 5 except wider DABS/IPC average is provided.

TABLE 2.2
UG3RD EQUIPMENT
SITING ASSUMPTIONS

WVAS and Terminal Automation - Configurations 1 through 5

Chicago O'Hare (ORD)
Atlanta International (ATL)
Los Angeles (LAX)
John F. Kennedy International (JFK)
San Francisco (SFO)
La Guardia (LGA)
Miami (MIA)
Washington National (DCA)
Boston (BOS)
Denver (DEN)

Pittsburg Greater (PIT)
Detroit Wayne (DTW)
Dallas Love Field (DAL)
St. Louis International (STL)
Philadelphia (PHL)
Newark (EWR)
Minneapolis Wold Chamber (MSP)
Cleveland Hopkins Intl (CLF)
Dallas-Fort Worth (DFW)
Houston International (IAH)

Honolulu (HNL)
Memphis (MEM)
Seattle Tacoma International (SEA)
Kansas City International (MCI)
New Orleans Moisant (MSY)
Tampa (TPA)
Las Vegas (LAS)
Indianapolis (IND)
Phoenix (PHX)
Covington Gr. Cinn. (CVG)

DABS/IPC equipment - Configurations 2 and 4

30 Terminals listed above, concentration of remaining units to provide complete center area coverage in one third of the enroute centers.

DABS/IPC equipment - Configurations 3 and 5

30 Terminals listed above, complete center area coverage in all enroute centers.

TABLE 2.3
ASSUMED DATES OF
OPERATIONAL CAPABILITY

UG3RD Configuration	Operation Date
1	1985
2	1990
3	1990
4	1990
5	1990

Specific subprograms creating staff savings are data distribution and basic metering and spacing. WVAS, other subprograms of upgraded air traffic control automation, and DABS in isolation, are not expected to alter staffing requirements. Productivity effects of individual components are discussed below.

2.2.1.1 Wake Vortex Avoidance System

WVAS will detect and predict conditions of wake vortices behind large/heavy aircraft during low speed final approach or departure. Resulting safety improvements and reduced aircraft separation requirements should increase runway capacities. Aircraft delays would be reduced, but with no inherent effect on tower staffing.

2.2.1.2 Upgraded Air Traffic Control Automation

Automated Data Distribution

This component includes the implementation at enroute and terminal control positions of an electronic tabular flight data display. The tabular display is an electronic flight data presentation designed to replace paper flight strips and attendant manual activities. The resulting reduction in control workload requirements per aircraft would increase sector traffic handling capabilities, and thereby effect staffing reduction. Assuming adequate back-up to the tabular display would justify removing flight strip printers, additional staffing reductions would be realized at enroute centers where a significant number of personnel are currently required to distribute flight strips. Similar, but less dramatic effects, would occur at terminal facilities where relatively few people are directly involved in flight strip distribution.

Terminal Area Basic Metering and Spacing

Basic metering and sequencing is an optimizing process to maximize airport runway utilization by precisely controlling interarrival times at runway thresholds. Suggested control instructions regarding aircraft headings, speeds, and altitude would be issued to TRACON controllers by the computerized metering and sequencing operation. Some degree of workload reductions would be realized because of reduced controller decision time needed to mentally assess and determine aircraft sequence assignment, and the reduction of conflicts along in-bound flight paths. These workload reductions are expected to justify staffing reductions.

Terminal Area Advanced Metering and Spacing

Advanced metering and spacing will extend the service to departures and multiple airports in complex terminal areas. Because no fundamental change is introduced by advanced metering and sequence relative to the basic one, no additional staffing effects are assumed.

En Route Metering

This en route ATC component is an extension of terminal metering and sequencing. En route metering would require en route controllers to set up aircraft spacings in accordance with time-varying terminal metering specifications. Based on observations of procedures for controlling the movement rate of aircraft from the en route into the terminal airspace, significant impacts are not anticipated on controller workload.

Minimum Safe Altitude Warning (MSAW)

MSAW would advise TRACON radar controllers of minimum altitude violations. Because it would operate in situations that are not related to routine activity, MSAW is assumed to be a safety enhancement device that would not directly impact staffing requirements.

Conflict Alert

This automation component will project minimum separation violations a few minutes ahead of their occurrence, and accordingly warn the controller (suggested resolutions might be included). Since this device would operate on imminent potential conflict situations that occasionally may be "missed" by the controllers, it will not impact on routine control workload. The conflict alert is a very useful safety enhancement, but is not expected to affect staffing needs.

Automated Local Flow Control

Local flow control is designed to maximize sector capacity utilization by smoothing out traffic peaking situations. It would govern traffic flow on routes by means of an on-line computerized traffic planning process that regulates workload surges in accordance with the traffic handling capabilities of a multisector environment. Based on previous ATC studies, it appears that (by constraining traffic peaks and their concurrent workload surges) this operation is capable of regulating hourly manning needs, and thereby realizing staffing reductions.

Central Flow Control

Automation will introduce dynamic on-line data update capability into current central flow control and related operations. The resulting improvement in traffic demand estimation for major terminals and along major corridors would support the other terminal en route flow metering/ management components, but is not in itself expected to significantly affect staffing needs.

2.2.2 Configurations 2 and 4

These configurations involve DABS implementation at 100 sites. DABS would be combined with IPC in Configuration 4.

2.2.2.1 DABS Surveillance and Data Link

DABS surveillance, as an alternative to current ATCRBS, is intended to provide high-reliability, high-accuracy, and high-capacity aircraft situation data acquisition capabilities necessary to support control-by-exception automation. Data link capability is inherent in the DABS design, and is an alternative to independent VHF/UHF data link. The DABS system, by itself (without automation) will not significantly affect staffing, but data link is necessary to obtain staff savings from control message automation.

2.2.2.2 Intermittent Positive Control

IPC would provide traffic advisories and threat avoidance commands to pilots on a need-to-know basis. It would operate in conjunction with control message automation. DABS, IPC, and control message automation form the basis for air traffic control by exception where the controller's role would change to that of system manager.

2.2.2.3 Control Message Automation

The computerized control message automation operation will transmit digital data, including routine clearances and conflict avoidance directives to pilots. These transmissions would be compatible with the en route and terminal metering and flow management operations, but would not include extensive or nonstandard-format messages. Control sector design would enable controllers to maintain cognizance of the computerized control operation and intervene when necessary to adjust procedural rules, respond to pilot requests, and resolve non-standard situations. The resulting automation of certain

routine and conflict tasks should increase controller traffic handling capacities (by reducing workload per aircraft and permitting more efficient sector/radar complex manning strategies) and thereby permit staffing reductions.

2.2.3 Configurations 3 and 5

Differences in productivity impacts between UG3RD system Configurations 2 and 4, and Configurations 3 and 5, result from the degree to which DABS coverage is provided along airways thus permitting adoption of the man-as-a-manager concept. Under Configurations 3 and 5, equipment would be installed at 300 sites.

3.0 Estimates of Air Traffic Service Staff Savings at En Route Centers

This chapter presents estimates of the number of controllers and air traffic support personnel which will be required over the period 1980, the point when UG3RD air traffic control begins to be implemented, through 2000. Staff estimates are provided for three separate scenarios:

1. Continuation of the present ATC System
2. Implementation of UG3RD Configuration 1
3. Implementation of UG3RD Configurations 3 and 5

The value of staff savings associated with Configuration 1 through 5 is also calculated.

3.1 Estimates of Staff Requirements

Table 3.1 presents data on aircraft operations and staffing at en route centers for the years 1974 and 1975. Operations data are based on "busy" day traffic reports [2] for the year 1974 (the most recent data available at the inception of this study). The "calculated" staff given in Table 3.1 represents the estimate of required staff as derived by application of FAA formal staffing standards [8] to the 1974 operations statistics. "Actual on-board" staff is shown for comparison purposes. Differences between the two series are accounted for by the presence of trainees in the centers and other personnel considerations.

Data given in Table 3.1, forecasts of en route center operations [13], existing FAA staffing standards [8], and results of the Stanford Research Institute study of UG3RD impacts at the Los Angeles Center [6] were used to estimate future en route staffing requirements at all centers, assuming either a continuation of the present ATC system or introduction of various alternative UG3RD system configurations. The procedure employed assumes that staffing growth characteristics of the 20 center system will be the same as those of the Los Angeles center under comparable traffic growth patterns. 1/

1/ Subsequent to the completion of these estimates and their incorporation in the UG3RD system cost-benefit analysis [9], additional data on the anticipated impact of UG3RD improvements on staff requirements at the Atlanta Center became available [4]. Total en route staff requirements for various UG3RD configurations based on an average of Los Angeles and Atlanta Center results differ by only 6 percent from estimates based on Los Angeles alone.

TABLE 3.1
ARTCC OPERATIONS AND STAFFING STATISTICS
1974 AND 1975

Region	Center	Location	1974 Number of Sectors 1/	1974 Reported Air Traffic Service Staff: Calculated	1974 Reported Air Traffic Service Staff: Actual On-Board	Annual IFR Operations Handled (000) 2/: 1974	Annual IFR Operations Handled (000) 2/: 1975 (Estimated)
Central (ACE)	Kansas City	Olathe, Kansas	31	450	512	1000	1085
Eastern (AEA)	Washington	Leesburg, Virginia	35	593	622	1338	1495
	New York	Islip, New York	42	569	811	1530	1628
Great Lakes (AEL)	Indianapolis	Indianapolis, Indiana	33	661	590	1264	1359
	Cleveland	Oberlin, Ohio	43	701	664	1645	1767
	Minneapolis	Farmington, Minnesota	27	334	410	926	905
	Chicago	Aurora, Illinois	39	764	717	1660	1808
Northeast (ANW)	Seattle	Auburn, Washington	18	257	282	632	642
New England (ANE)	Boston	Nashua, New Hampshire	27	428	523	914	960
Rocky Mount (ARM)	Salt Lake City	Salt Lake City, Utah	18	252	277	408	437
	Great Falls	Great Falls, Montana	4	84	66	191	206
	Denver	Longmont, Colorado	29	390	391	634	642
Southern (ASO)	Jacksonville	Hillard, Florida	35	544	552	1063	1189
	Memphis	Memphis, Tennessee	29	456	462	1092	1083
	Miami	Miami, Florida	28	414	422	1027	1154
	Atlanta	Hampton, Georgia	39	559	641	1410	1453
Southwest (ASW)	Albuquerque	Albuquerque, NM	31	428	465	863	1016
	Houston	Houston, Texas	32	490	515	1098	1237
	Fort Worth	Fort Worth, Texas	39	456	503	1242	1314
Western (AWE)	Oakland	Fremont, California	27	379	459	892	952
	Los Angeles	Palmdale, California	31	415	452	1021	1036

1/ Source: "Past Year 1974 ARTCC ADP Run," Computer printout manuscript, Air Traffic Service (AAT-130), FAA (1975)

2/ Source: "IFR Aircraft Handled by User Category," [12].

The Los Angeles Center case study [6] determined controller manning requirements for a selected multisector area of the center alternately assuming the present ATC system, UG3RD Configuration 1 and Configurations 3 and 5. From this area sample, Air Traffic Service staff estimates were developed for the whole facility. The estimates include the minimum controller, supervisory, and support personnel needed to operate the facility with each en route configuration, but do not include controller trainee requirements. To allow for the handling of additional traffic demand at the current level of delay, alternative sector configuration strategies (based strictly on sector splits) and alternative sector manning strategies (increasing the number of sector team positions when feasible) were modeled. 1/ The estimated controller staffing requirements are summarized in Figure 3.1. Also included in Figure 3.1 are appropriate increases in noncontroller personnel.

Estimates of Los Angeles Center staff requirements utilize two models developed by the Stanford Research Institute. The first model, termed the Relative Capacity Estimating Process (RECEP), relates controller workload requirements to sector traffic capacities. The second, the Air Traffic Flow (ATF) network simulation model, assesses traffic capacity and delay in a multisector environment. When preparing staff requirement estimates, functional and equipment descriptions of the various UG3RD configurations were translated into changes to current controller task activities. Revised task activities were formulated into the RECEP model to determine sector capacities for each UG3RD configuration. Individual sector capacities were then integrated into the ATF model to determine the traffic capacity and delay characteristics of a selected multisector area of the Los Angeles Center. This information was used to estimate manning requirements under each configuration during the peak shift of the peak day which in turn was used to estimate annual staffing to traffic relationships.

1/ The development of the staffing estimates is extensively documented in _Case Study of the Upgraded Third Generation En Route ATC Staffing Requirements for the Los Angeles Center_ [6].

FIGURE 3.1
RELATIONSHIP OF ENROUTE CENTER AIR TRAFFIC STAFFING LEVELS TO TRAFFIC LEVELS

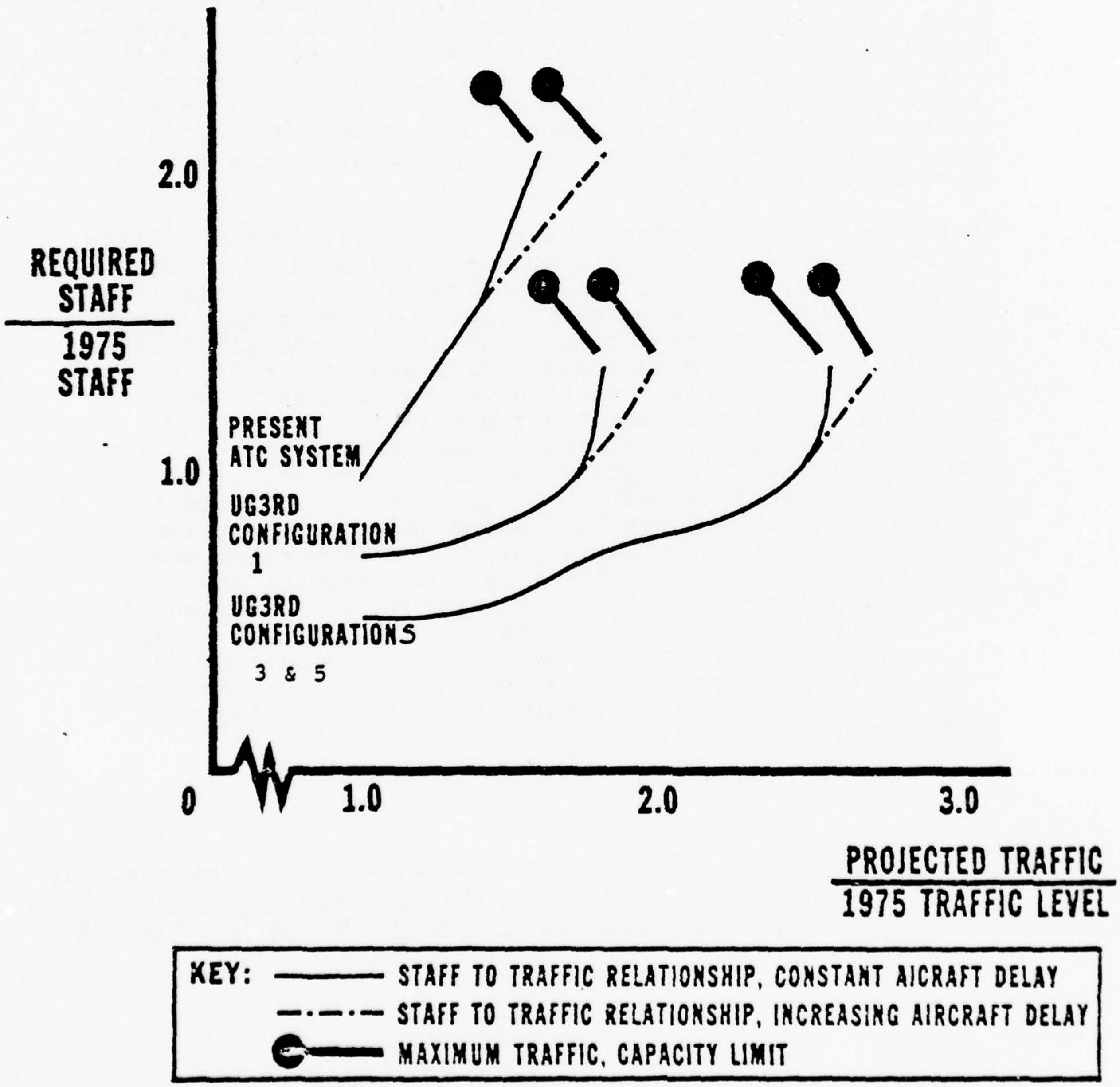

Figure 3.1 illustrates estimated staffing increases required to accomodate increased numbers of operations while maintaining current average delays. Under the present ATC system, the current level of aircraft delay could be maintained in spite of increased numbers of operations by increasing staffing until the operations grow to 150 percent of the 1975 level. At this traffic level, the maximum sectorization (an 80 percent increase in the number control sectors) is achieved and the sectors cannot be further split effectively. Additional operations can be accomodated beyond the 150 percent traffic level only by increasing delay. However, a practical difficulty should be considered. With reference to Figure 3.1, a sharp increase in base case staffing needs occurs at the 140 percent traffic level, while the corresponding increase in traffic handling capacity is nearly negligible. A staffing strategy at this level of operations oriented toward no increase in aircraft delay is unrealistic and produces low marginal productivity returns. A practical staffing limit for maintaining current average delay appears to be reached at the 140 percent traffic level. Thus, gradual staffing increases beyond the 140 percent traffic level are associated with increased aircraft delay until the maximum staffing limit is reached at 180 percent of the 1975 traffic level.

Similar staffing extrapolations for UG3RD configurations, are also illustrated in Figure 3.1. These curves were used to develop annual staffing factors shown in Table 3.2. Staffing factors in Table 3.2 are assumed to apply to the 20-center enroute system, although based on the Los Angeles Center analysis. Because the Los Angeles Center analysis observed 1975 traffic and staffing levels exclusive of training requirements, corresponding 20-center staffing base estimates for 1975 are required. Using Table 3.1 as a reference, the 20-center 1974 Air Traffic Service calculated staff is 9,264 persons, while the actual on-board staff is 10,336. For the present analysis it is assumed that the latter number is indicative of 1975 staffing requirements, and 10,300 persons was taken as the 20-center 1975 staffing base.

Using Table 3.2, annual staffing factors corresponding to FAA traffic forecasts [13] were determined for the 20-center system for each year of the FY1980 to 2000 time frame as shown in Table 3.3. Using the projected annual staffing factors, the 1975 staffing base (10,300 persons) was expanded to obtain the annual staffing estimates shown in Table 3.4.

TABLE 3.2
AIR TRAFFIC SERVICE EN ROUTE CENTER STAFFING FACTORS ASSOCIATED WITH RELATIVE TRAFFIC LEVELS 1/

Ratio Future Traffic to 1975 Traffic	Annual Staffing Factor (Ratio Future Staff Requirement to 1975 Staffing): Present ATC System	UG3RD Configuration 1	UG3RD Configurations 3 and 5
1.00	1.00 2/	.80	.56
1.20	1.28	.80	.56
1.30		.80 2/	
1.40	1.59 3/	.83	.56 2/
1.60	1.87	.92	.62
1.80	2.14 4/	1.12 3/	.74
2.00	2.14 4/	1.38 4/	.90
2.20	2.14 4/	1.38 4/	.98
2.40	2.14 4/	1.38 4/	1.10
2.45			1.15 3/
2.60	2.14 4/	1.38 4/	1.27
2.75			1.39 4/
2.80	2.14 4/	1.38 4/	1.39 4/
3.00	2.14 4/	1.38 4/	1.39 4/

1/ Factors based on Case Study of the UG3RD En Route ATC System Staffing Requirements for the L.A. Center [6].

2/ Minimum staffing at current average delay.

3/ Practical maximum staffing at current average delay.

4/ Maximum staffing at maximum sectorization constraint.

TABLE 3.3

AIR TRAFFIC SERVICE ENROUTE CENTER STAFFING FACTORS IN THE PERIOD 1980-2000

Year	Traffic Level Relative to 1975 Level 1/	Present ATC System	Annual Staffing Factor UG3RD Configuration 1 2/	(Ratio Required Staff to 1975 Staffing) UG3RD Configurations 3&5 3/
1980	1.22	1.34	--	--
1981	1.29	1.41	--	--
1982	1.36	1.53	--	--
1983	1.43	1.63	--	--
1984	1.49	1.72	--	--
1985	1.57	1.83	.91 4/	--
1986	1.63	1.91	.94 4/	--
1987	1.75	2.07	1.07 4/	--
1988	1.83	2.14	1.16	--
1989	1.95	2.14	1.32	--
1990	2.06	2.14	1.38	.92 4/
1991	2.13	2.14	1.38	.95 4/
1992	2.19	2.14	1.38	.98 4/
1993	2.26	2.14	1.38	1.02 4/
1994	2.33	2.14	1.38	1.06 4/
1995	2.40	2.14	1.38	1.10 4/
1996	2.47	2.14	1.38	1.16
1997	2.54	2.14	1.38	1.22
1998	2.60	2.14	1.38	1.27
1999	2.67	2.14	1.38	1.31
2000	--	--	1.38	1.31

1/ Traffic forecasts obtained from IFR Aircraft Handled by User Category. [12].

2/ Configuration 1 becomes fully operational in 1985.

3/ Configurations 3 and 5 become fully operational in 1990.

4/ Staffing at current dollar level.

TABLE 3.4

ENROUTE CENTER STAFF REQUIREMENTS

Year	Present ATC System	UG3RD Configuration 1 1/	UG3RD Configurations 3 and 5 2/
1980	13802	13802	13802
1981	14523	12188	12051
1982	15759	10574	10300
1983	16789	8961	8549
1984	17716	9167	8961
1985	18849	9373	9373
1986	19673	9682	9682
1987	21321	11021	11021
1988	22042	11948	11948
1989	22042	13596	10712
1990	22042	14214	9476
1991	22042	14214	9785
1992	22042	14214	10094
1993	22042	14214	10506
1994	22042	14214	10918
1995	11041	14214	11330
1996	22042	14214	11948
1997	22042	14214	12566
1998	22042	14214	13081
1999	22042	14214	13493

1/ Staff requirements for period 1980 through 1983 represent interpolation between 1980 requirements under present ATC system and 1983 requirements under fully operational configuration 1.

2/ Staff requirements for period 1980 - 1990 represent interpolation between requirements under present system for 1980, requirements for configuration 1 in 1983, and requirements for 1990 under Configuration 5.

3.2 Estimate of Staff Savings

To calculate controller staff savings at en route centers associated with various UG3RD configurations, staff requirements given in Table 3.4 were subtracted from requirements assuming a continuation of the present ATC system. The differential was then multiplied by an average wage plus benefits cost of $24,795 to determine the value of staff savings for UG3RD Configuration 1 and Configurations 3 and 5. For Configurations 2 and 4, savings were estimated as savings for Configuration 1, plus one-third of the difference in savings between Configuration 1 and Configurations 3 and 5. Estimated staff savings are given in Table 3.5.

TABLE 3.5

ESTIMATED UG3RD STAFF
SAVINGS AT ENROUTE CENTERS
(MILLION 1975 $)

Year	Configuration 1	Configurations 2 and 4	Configurations 3 and 5
1980	--	--	--
1981	$57.9	$61.3	$61.3
1982	128.6	135.4	135.4
1983	194.1	204.3	204.3
1984	212.0	217.1	217.1
1985	235.0	235.0	235.0
1986	247.7	247.7	247.7
1987	255.4	255.4	255.4
1988	250.3	250.3	250.3
1989	209.4	233.2	280.9
1990	194.1	233.3	311.6
1991	194.1	230.7	303.9
1992	194.1	228.2	296.3
1993	194.1	224.7	286.0
1994	194.1	221.3	275.8
1995	194.1	217.9	265.6
1996	194.1	212.8	234.9
1997	194.1	207.7	234.9
1998	194.1	203.5	222.2
1999	194.1	200.1	212.0
2000	194.1	196.7	201.9
Total	$3,925.5	$4,216.6	$4,747.9

4.0 Estimates of Air Traffic Service Staff Savings at 30 Selected Terminals

Estimates of future air traffic control staff requirements at 30 selected terminals (see Table 2.2) are presented in this chapter under three different assumptions:

1. Continuation of the present ATC system.
2. Implementation of UG3RD Configuration 1.
3. Implementation of UG3RD Configurations 2 through 5.

In addition, estimates of the value of staff savings associated with various UG3RD configurations are given.

Estimation procedures use available statistics on terminal facilities and the results of research on terminal area controller operations and staffing at selected sites conducted by Metis Corporation [11] to estimate staffing requirements for various ATC configurations for each of the 30 terminals. It is assumed that the staffing growth characteristics of each of the 30 terminals will be similar to those of the sample sites under comparable traffic growth patterns.

4.1 Estimate of Staff Requirements

Table 4.1 contains historical data on air traffic control staff levels and air traffic operations for 30 terminals being evaluated as UG3RD sites. Air traffic statistics are based on 1974 busy day counts [3], the most recent data available at the inception of this study. Calculated staff was determined by application of existing FAA staffing standards [8] to busy day data. The 1974 calculated staff was used in projecting future staff requirements for each facility (see description below). Controller staff estimates given in Table 4.1 include terminal radar approach control (TRACON) and tower cab requirements. At some terminal sites, TRACONS and towers are separate facilities, each with its own support and data systems staff (including administrative, supervisory, planning, and secretarial personnel). The remainder of this section describes the estimation of future TRACON and tower controller and support and data system personnel requirements for each of the facilities assuming a continuation of the present ATC system and various UG3RD configurations. Staffing requirements are estimated for the period 1980 through 2000 at five-year intervals.

TABLE 4.1

1974 STAFF AND OPERATION STATISTICS FOR SELECTED TERMINALS AND ASSOCIATED TRACONS

Facility Site	ID	Facility Description	1974 Calculated Annual Staff: Controller CAB	Controller TRACON	Controller Total	Support and Data Systems	Facility Total	1974 Traffic Data: CAB Work-Load Units 1/	TRACON Peak Day Operations
Kansas City	MCI	TRACON/Tower	16	34	50	18	68	223	886
St. Louis	STL	TRACON/Tower	21	39	60	22	82	463	1670
New York	EAN	TRACON	-	119	119	34	153	-	4882
-Kennedy	JFK	Tower	25	-	25	7	32	744	-
-La Guardia	LGA	Tower	25	-	25	7	32	726	-
-Newark	EWR	Tower	19	-	19	7	26	441	-
Philadelphia	PHL	TRACON/Tower	20	37	57	22	79	438	1269
Pittsburgh	PIT	TRACON/Tower	20	31	51	18	69	435	1167
Washington	DCA	TRACON/Tower	22	54	76	26	102	520	2228
Chicago	ORD	TRACON/Tower	30	86	116	37	153	1021	5242
Cleveland	CLE	TRACON/Tower	19	34	53	18	71	369	1323
Detroit	DTW	TRACON/Tower	20	56	76	23	99	383	2210
Minneapolis	MSP	TRACON/Tower	19	31	50	18	68	343	1229
Boston	BOS	TRACON/Tower	21	32	53	18	71	466	1326
Seattle	SEA	TRACON/Tower	16	28	44	18	62	246	1023
Honolulu	HNL	TRACON/Tower	19	20	39	14	53	363	757
Denver	DEN	TRACON/Tower	22	32	54	21	75	522	1208

1/ CAB Workload Units = $\frac{\text{Annual Itinerant Ops.}}{1000} + \frac{(.5 \times \text{Annual Local Ops.})}{1000} + \frac{(.3 \times \text{Annual Primary Airport Instrument Ops.})}{1000}$

TABLE 4.1 (Cont'd.)

1974 STAFF AND OPERATION STATISTICS FOR SELECTED TERMINALS AND ASSOCIATED TRACONS

Facility Site	ID	Facility Description	1974 Calculated Annual Staff: Controller CAB	Controller TRACON	Controller Total	Support and Data Systems	Facility Total	1974 Traffic Data: CAB Work-Load Units 1/	TRACON Peak Day Operations
Atlanta	ATL	TRACON/Tower	26	54	80	26	106	745	2829
Miami	MIA	TRACON/Tower	22	40	62	25	87	491	1801
Tampa	TPA	TRACON/Tower	17	39	56	22	78	293	1483
Dallas/Ft.Worth	DEW	TRACON/Tower	17	51	68	22	90	283	2192
Houston	IAH	TRACON/Tower	13	40	56	22	78	283	2262
New Orleans	MSY	TRACON/Tower	13	25	41	14	55	213	984
Las Vegas	LAS	TRACON/Tower	16	30	46	18	64	276	1311
Los Angeles	LAX	TRACON	-	42	42	14	56	-	1926
-Los Angeles	LAX	Tower	28	-	28	11	39	965	-
Oakland	OAK	TRACON	-	66	66	22	88	-	2524
-San Francisco	SFO	Tower	24	-	24	7	31	678	-
Phoenix	PHX	TRACON	-	35	35	11	46	-	1502
Covington,Cinn.	CVG	TRACON/Tower	13	22	35	14	49	201	793
Dallas Love Field	DAL	-	22	-	22	8	30	568	-
Indianapolis	IND	TRACON/Tower	16	28	44	19	63	292	838
Memphis	MEM	TRACON/Tower	20	26	46	18	64	373	1037

1/ CAB Workload Units = $\frac{\text{Annual Itinerant Ops.}}{1000} + \frac{(.5 \times \text{Annual Local Ops.})}{1000} + \frac{(.3 \times \text{Annual Primary Airport Instrument Ops.})}{1000}$

4.1.1. TRACON Staff Requirements

As part of a previous contract effort for the FAA, TRACON manning and staffing requirements were estimated by Metis Corporation for two selected sites, Jacksonville and Atlanta, and for three traffic levels. These estimates correspond to the following ATC scenarios:

1. Continuation of the present ATC system.
2. UG3RD Configuration 1.
3. UG3RD Configurations 2 through 5.

In developing these staffing estimates, workload modeling techniques were used to a limited extent, but the estimates also incorporate the judgment and opinions of FAA personnel at the two study sites.

In order to provide supplemental TRACON controller staffing information, Stanford Research Institute independently developed controller manning estimates for two additional sites--Boston and Washington National Airport--using previously developed workload modeling techniques. For convenience, the 1974 busy-day, day-shift (which is the peak shift for that day at the two sites) manning data was used as a base for estimating future manning requirements. Day-shift manning requirements using workload dependent controller traffic capacity estimates were estimated for both sites for a range of traffic levels. 1/

Day-shift manning factor estimates for Jacksonville, Atlanta, Boston, and Washington National are presented in Table 4.2. Composite relationships between staff requirements and traffic levels taken from Table 4.2 are shown in Figure 4.1. Annual staffing requirements are assumed directly proportional to the busy-day, day-shift manning requirements. Using Figure 4.1. TRACON controller annual staffing factors for a range of traffic levels are obtained by interpolation and presented in Table 4.3. These staffing factors are assumed to apply to all TRACONS associated with terminals listed in Table 2.2.

1/ TRACON controller estimation manning techniques are documented in A First Cut Procedure for Estimating TRACON Controller Manning Requirements [10].

TABLE 4.2

TRACON CONTROLLER DAY-SHIFT MANNING FACTOR ESTIMATES FOR FOUR SAMPLE SITES

		Day-Shift Manning Factor (Ratio Required Staff to 1974) Staff		
Traffic Level (1974 Base)	TRACON Site	Present ATC System	UG3RD Configuration 1	UG3RD Configurations 2 through 5
1.0	ATL 1/	1.0	NA	NA
	JAX 1/	1.0	NA	NA
	BOS 2/	1.0	1.0	0.56
	DCA 2/	1.0	0.73	0.54
1.5	BOS 2/	1.67	1.22	0.89
	DCA 2/	1.54	1.08	0.92
1.51	ATL 1/	1.47	1.35	0.71
2.0	BOS 2/	2.0	1.78	0.89
	DCA 2/	2.31	1.77	1.08
2.17	JAX 1/	2.0	1.69	0.92
3.0	BOS 2/	2.89	2.22	1.44
	DCA 2/	3.85	2.77	1.54

1/ ATL JAX factors obtained from ARTS III Enhancement Costs and Benefits.

2/ BOS and DCA Factors based on SRI RECEP estimates obtained from The Air Traffic Controller's Contribution to ATC System Capacity in Manual and Automated Environments, [16].

FIGURE 4.1

RELATIONSHIP TRACON DAY-SHIFT CONTROLLER STAFF TO TRAFFIC LEVELS

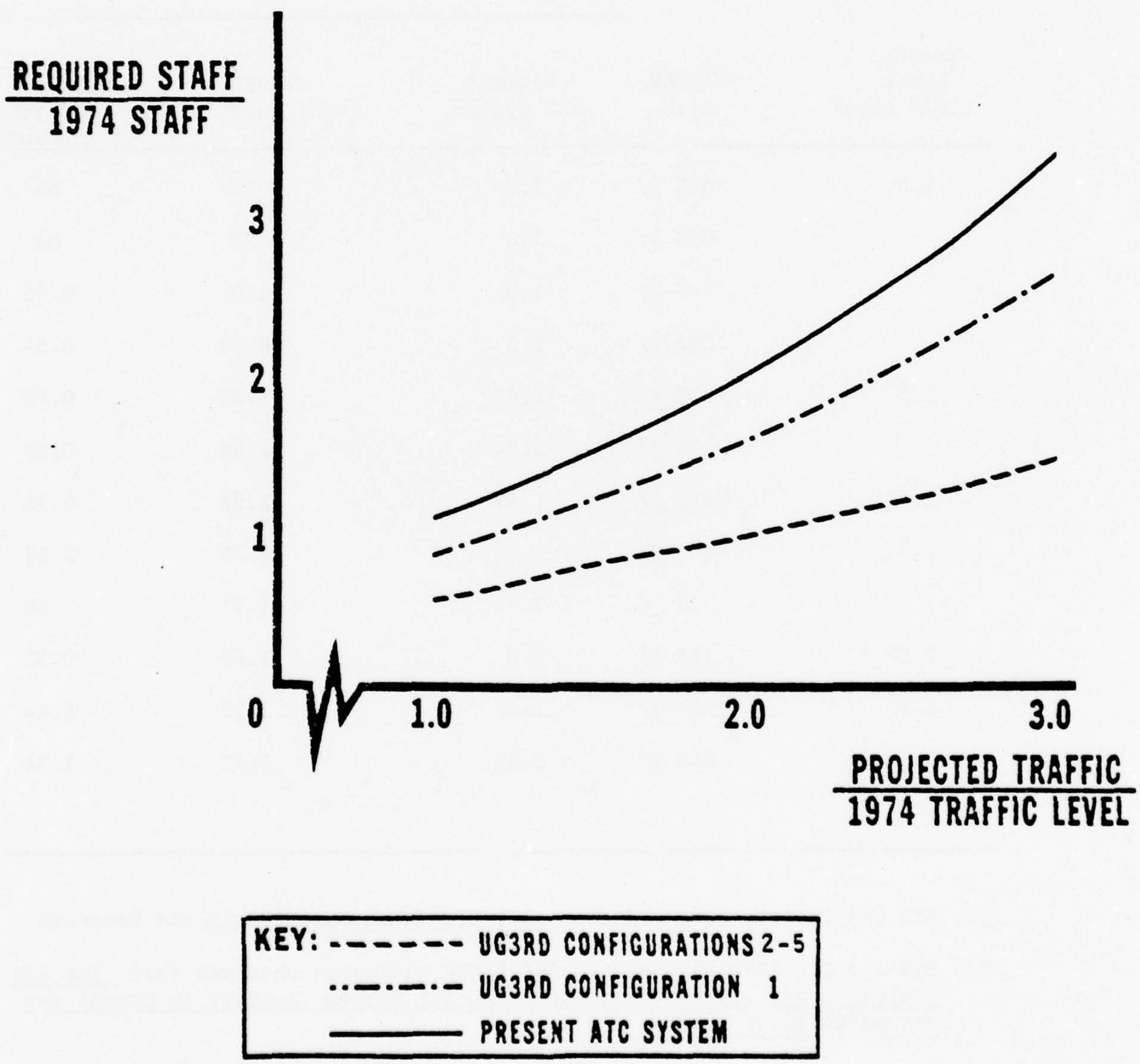

TABLE 4.3

TRACON CONTROLLER ANNUAL
STAFFING FACTOR ESTIMATES

	Staffing Factor (Ratio Required Staff) To 1974 Staff				
Operational Configuration / Ratio Forecast To 1974 Traffic Level	1.0	1.5	2.0	2.5	3.0
1. Present ATC System	1.0	1.5	2.1	2.65	3.40
2. UG3RD Configuration 1 Through 3	0.95	1.20	1.65	2.10	2.60
6. UG3RD Configuration 4 and 5	0.55	0.75	0.95	1.20	1.5

Controller annual staffing factors corresponding to each of the 30 TRACON's traffic forecast are given in Table 4.4. Using the annual staffing factors, each TRACON's 1974 controller staff was expanded to estimates of future staff requirements assuming a continuation of the present ATC system and various UG3RD configurations. Future TRACON staffing requirements are given in Tables 4.4, 4.5 and 4.6.

4.1.2. Tower Controller Staff Requirements

Future tower cab controller staffing requirements assuming a continuation of the present ATC system were established using the FAA staffing standards [8]. The standards, shown in Table 4.7, equate staff levels with measures of controller workload. Workload units are linear functions of traffic operations handled on the busy day:

$$\text{Cab Workload Units} = \frac{\text{Annual Itinerant Operations}}{1000} + \frac{.5(\text{Annual Local Ops})}{1000} + \frac{.5\ (\text{Annual Pri. Airport Inst Ops})}{1000}$$

The workload ranges given in Table 4.7 determine the number of tower cab controllers required for the day and evening shifts.

Workload units will increase in direct proportion to traffic growth given that workload units are a linear function of traffic level. To estimate future workload growth at the various terminals listed in Table 4.1, the 1974 workload units for the terminals were increased in proportion to the ratio of projected future terminal traffic to 1974 traffic levels. Staffing standards given in Table 4.7 were then used in combination with projected workload units to estimate future day and evening shift controller requirements assuming a continuation of the present ATC system. These estimates, adjusted for leave and other allowances, are the basis for annual requirements contained in Table 4.8.

To estimate staffing requirements for UG3RD Configuration 1, it was first assumed that the automatic data handling and flight data forwarding capabilities would eliminate the need for manning the flight data position in each tower.

TABLE 4.4

ESTIMATED TRACON CONTROLLER ANNUAL STAFF REQUIREMENTS - CONTINUATION OF PRESENT ATC SYSTEM

TRACON	Calculated 1974 Annual Staff	Estimated Staff Requirement (Persons)				
		1980	1985	1990	1995	2000
MCI	34	47	60	71	90	90
STL	39	48	54	59	63	65
EAN	119	139	158	171	184	192
PHL	37	47	49	53	57	61
PIT	31	40	45	50	53	57
DCA	54	51	48	48	48	48
ORD	86	95	95	95	95	95
CLE	34	44	44	44	44	44
DTW	56	68	74	78	81	84
MSP	31	47	58	64	69	72
BOS	32	39	41	43	44	46
SEA	28	34	37	42	50	56
HNL	20	22	24	27	27	28
DEN	32	34	36	37	39	41
ATL	54	66	69	72	81	84
MIA	40	44	51	56	60	64
TPA	39	59	82	106	133	138
DFW	51	62	73	82	90	93
IAH	40	53	66	78	88	100
MSY	25	38	49	58	72	74
LAS	30	40	45	48	53	55
LAX	42	47	49	54	54	56
OAK	66	81	88	102	106	114
PHX	35	43	49	54	60	64
CVG	22	29	37	46	55	57
IND	28	36	50	62	70	77
MEM	26	34	42	49	52	57

TABLE 4.5

ESTIMATED TRACON CONTROLLER ANNUAL STAFF REQUIREMENTS - UG3RD SYSTEM CONFIGURATION 1

TRACON	Calculated 1974 Annual Staff	Estimated Staff Requirement			
		1985	1990	1995	2000
MCI	34	47	56	71	71
STL	39	44	46	49	50
EAN	119	131	137	143	149
PHIL	37	41	43	44	48
PIT	31	36	39	42	44
DCA	54	49	49	49	49
ORD	86	86	86	86	86
CLE	34	37	37	37	37
DTW	56	62	63	64	66
MSP	31	46	50	54	57
BOS	32	35	35	36	37
SEA	28	31	33	39	44
HNL	20	21	22	22	23
DEN	32	32	33	34	35
ATL	54	58	59	64	65
TPA	39	64	84	101	105
DFW	51	59	64	70	73
IAH	40	52	61	70	79
MSY	25	38	46	56	58
LAS	30	35	38	40	43
LAX	42	43	45	45	46
OAK	66	73	79	83	88
PHX	35	40	42	47	50
CVG	22	28	35	42	46
IND	28	36	44	52	57
MEM	26	33	39	42	44
MIA	40	43	45	47	50

TABLE 4.6

ESTIMATED TRACON CONTROLLER ANNUAL STAFF REQUIREMENTS - UG3RD SYSTEM CONFIGURATION 2 THROUGH 5

TRACON	Calculated 1974 Annual Staff	Estimated Staff Requirement			
		1985	1990	1995	2000
MCI	34	28	32	41	41
STL	39	27	28	30	31
EAN	119	80	84	89	92
PHL	37	25	26	28	29
PIT	31	22	24	25	26
DCA	54	28	28	28	28
ORD	86	51	51	51	51
CLE	34	22	22	22	22
DTW	56	38	39	40	41
MSP	31	27	29	31	33
BOS	32	21	21	22	23
SEA	28	19	20	23	25
HNL	20	13	13	13	14
DEN	32	19	20	20	21
ATL	54	35	36	39	41
MIA	40	26	28	29	31
TPA	39	37	48	59	61
DFW	51	36	39	42	43
IAH	40	32	36	40	45
MSY	25	22	26	32	33
LAS	30	22	23	24	26
LAX	42	26	27	27	28
OAK	66	44	50	51	53
PHX	35	24	26	28	30
CVG	22	18	20	24	26
IND	28	22	28	31	34
MEM	26	21	23	23	26

TABLE 4.7

TOWER CAB MANNING STANDARD TABLE

Total Day & Eve. Controller Positions	CAB WORKLOAD UNIT RANGE Tracon/ Tower	Tower
3.0	0-50	
3.5	51-59	
4.0	50-75	
4.5	76-93	135-159
5.0	94-113	160-185
5.5	114-135	186-213
6.0	136-158	214-240
6.5	159-183	241-285
7.0	184-210	286-301
7.5	211-238	302-333
8.0	239-269	334-365
8.5	270-301	366-399
9.0	302-335	400-434
9.5	336-371	435-468
10.0	372-408	469-506
10.5	409-447	507-537
11.0	448-488	538-564
11.5	489-530	565-596
12.0	531-574	597-639
12.5	575-620	640-668
13.0	621-668	669-711
13.5	669-717	712-762
14.0	718-768	763-817
14.5	769-821	781-884
15.0	822-875	885-961
15.5	876-931	962-1054
16.0	932-989	1055-1165
16.5	990-1048	1166-1303
17.0	1049 & UP	1304-1479
17.5		1480-1707
18.0		1708 & UP

Assuming that the flight data position is manned during both the day and evening shifts, and accounting for sufficient personnel to cover periods of leave, it is estimated that each tower's controller staff requirements would be reduced by three persons. Tower staffing requirements were therefore calculated as three persons less than given in Table 4.8.

For Configurations 2 through 5, the data-link based control-by-exception operation is assumed to eliminate the need for manned clearance delivery positions in each tower. Considering shift and leave requirements, elimination of this position reduces each tower's manning requirements by six controllers.

4.1.3. Support and Data System Requirements

To complete the estimates of future terminal air traffic staff, data systems and support personnel requirements were added to the TRACON and tower controller staff requirements for each alternative UG3RD configuration. Support and data systems personnel requirement for each facility were estimated using staffing standards established by the FAA. As can be seen in Table 4.9, these standards make annual support staffing requirements dependent on facility controller staffing, while data systems staff is constant.

Staffing requirements calculated from the standards for 1974 were compared with actual 1974 staff. The FAA calculated staff exceeded requirements. Local excesses in staffing requirements were allowed for in the 1974 staffing base. Using the TRACON and tower controller requirements previously estimated and the indicated local excess allowances, support and data systems staffing requirements were calculated for each terminal facility.

4.1.4 Total Air Traffic Staffing

Tables 4.10 through 4.12 summarize total terminal area air traffic staffing requirements--TRACON controllers, tower cab controllers, and support staff. Estimates of each of these requirements have been described above. TRACON controller requirements for New York and the San Francisco - Oakland areas were apportioned to individual terminals based on the relative size of tower cab controller staffs.

TABLE 4.8

ESTIMATED TOWER CAB ANNUAL STAFF REQUIREMENTS - CONTINUATION OF PRESENT ATC SYSTEM

	1974 Calculated Staff			Estimated Annual Staff Requirement 2/				
Tower	Annual	Peak-day Day & Eve. Shift	Staffing Ratio 1/	1980	1985	1990	1995	2000
MCI	16	7.5	2.13	19	21	23	27	27
STL	21	11.0	1.91	23	25	26	27	27
JFK	25	13.5	1.85	28	29	30	30	31
LGA	25	13.5	1.85	25	26	27	27	27
EWR	19	9.5	2.0	21	24	26	28	28
PHL	20	10.5	1.9	23	23	24	25	26
PIT	20	10.5	1.9	23	24	26	27	27
DCA	22	11.5	1.91	22	21	21	21	21
ORD	30	16.5	1.82	31	31	31	31	31
CLE	19	9.5	2.0	22	22	22	22	22
DTW	20	10.0	2.0	22	23	23	24	24
MSP	19	2.5	2.0	23	25	27	28	28
BOS	21	11.0	1.91	23	24	24	25	25
SEA	16	8.0	2.0	17	18	19	21	22
HNL	19	9.5	2.0	20	21	22	22	23
DEN	22	11.5	1.91	23	23	24	25	25
ATL	26	14.0	1.86	29	29	30	32	32
MIA	22	11.5	1.91	23	24	25	26	27
TPA	17	8.5	2.0	21	25	28	31	31
DFW	17	8.5	2.0	19	20	21	22	23
IAH	16	8.5	1.88	18	21	22	24	24
MSY	16	8.0	2.0	19	22	24	26	26
LAS	16	8.5	1.88	18	19	20	21	21
LAX	28	15.5	1.81	29	29	30	30	30
SFO	24	13.0	1.85	26	27	29	29	30
CVG	13	5.0	2.6	18	20	23	26	28
DAL	22	11.0	2.0	28	28	28	28	28
IND	16	7.0	2.3	21	23	27	29	32
MEM	20	8.0	2.5	23	25	30	30	30

1/ Staffing ratio = $\frac{\text{Calculated 1974 Annual Staff Requirement}}{\text{Calculated 1974 Day and Evening Shift}}$

2/ Annual Staffing, year X = (Staffing ratio)(Day and Evening Manning estimate, year X)

TABLE 4.9

AIR TRAFFIC SERVICE TERMINAL FACILITY SUPPORT AND DATA SYSTEMS ANNUAL STAFFING STANDARD

	Minimum Required Annual Support Staff		
Number of Controllers	Support Staff	Data Systems	Total
1-8	1	3	4
9-12	4	3	7
13-18	5	3	8
19-26	7	3	10
27-43	11	3	14
44-54	14	3	17
55-70	17	3	20
71-99	19	3	22
100+	31	3	34

TABLE 4.10

ESTIMATED AIR TRAFFIC SERVICE ANNUAL
STAFF REQUIREMENTS AT 30 SELECTED TERMINALS -
CONTINUATION OF PRESENT ATC SYSTEM

FACILITY	1980	1985	1990	1995	2000
MCI	87	104	117	152	152
STL	95	103	109	114	116
JFK	67	73	75	76	79
LGA	56	61	69	70	74
EWR	50	58	61	72	75
PHL	92	96	101	106	111
PIT	84	90	99	103	107
DCA	99	93	93	93	93
ORD	163	163	163	163	163
CLE	87	87	87	87	87
DTW	113	120	136	140	143
MSP	91	106	114	120	135
BOS	83	86	88	90	94
SEA	69	76	82	94	101
HNL	56	62	66	66	68
DEN	81	83	85	88	90
ATL	121	124	140	151	154
JAX	89	99	107	116	121
MIA	92	102	108	113	118
TPA	104	143	170	200	205
DFW	105	117	139	148	152
IAH	95	111	136	148	160
MSY	77	93	104	120	134
LAS	79	85	89	97	99
LAX	107	109	115	115	120
SFO	141	153	181	185	194
CVG	47	57	69	81	85
DAL	28	28	28	28	28
IND	57	73	89	99	109
MEM	57	67	79	82	87

TABLE 4.11

ESTIMATED AIR TRAFFIC ANNUAL STAFF REQUIREMENTS AT 30 SELECTED TERMINALS - UG3RD SYSTEM CONFIGURATION 1

FACILITY	1985	1990	1995	2000
MCI	86	99	118	118
STL	88	91	97	98
JFK	58	63	65	68
LGA	54	54	54	55
EWR	50	51	55	57
PHL	83	86	88	95
PIT	78	83	87	89
DCA	91	91	91	91
ORD	151	151	151	151
CLE	77	77	77	77
DTW	107	110	112	114
MSP	89	97	102	105
BOS	77	77	79	80
SEA	64	67	78	84
HNL	53	55	55	57
DEN	73	75	80	81
ATL	110	112	119	120
JAX	83	87	96	100
MIA	89	92	95	101
TPA	110	145	165	169
DFW	100	106	113	117
IAH	92	104	115	136
MSY	77	87	101	103
LAS	69	76	79	82
LAX	90	97	97	98
SFO	126	136	140	150
CVG	45	55	65	71
DAL	25	25	25	25
IND	56	68	78	86
MEM	55	66	69	71

TABLE 4.12

ESTIMATED AIR TRAFFIC SERVICE ANNUAL
STAFF REQUIREMENTS AT 30 SELECTED TERMINALS -
UG3RD SYSTEM CONFIGURATIONS 2 THROUGH 5

FACILITY	1990	1995	2000
MCI	67	83	83
STL	67	70	71
JFK	70	76	74
LGA	65	64	65
EWR	62	67	67
PHL	63	66	68
PIT	62	64	65
DCA	64	64	64
ORD	101	101	101
CLE	53	53	53
DTW	77	79	80
MSP	68	71	76
BOS	54	56	57
SEA	48	53	56
HNL	43	43	45
DEN	56	57	58
ATL	84	89	91
JAX	58	65	66
MIA	69	71	74
TPA	92	108	110
DFW	73	80	82
IAH	71	80	85
MSY	61	69	70
LAS	52	54	56
LAX	65	65	66
SFO	96	97	100
CVG	37	44	48
DAL	22	22	22
IND	49	54	60
MEM	47	47	50

4.2. Estimates of Staff Savings

Air traffic service staff savings at 30 selected terminals (see Table 2.2) associated with various UG3RD configurations were estimated for the period 1976 through 2000. Estimated savings were calculated by first subtracting staff requirements for the various alternatives configurations given in Tables 4.11 and 4.12 from requirements assuming a continuation of the present ATC system (Table 4.10). This procedure yields estimates of manpower differentials in five-year increments. Annual manpower differentials were calculated by linear interpolation of the five-year interval estimates. These differentials were then multiplied by an average 1975 wage plus benefits cost of $24,795 to determine the value of staff savings for UG3RD configurations. Estimated staff savings for the 20-year period are given for 30 selected terminals in Table 4.13.

TABLE 4.13

ESTIMATED UG3RD STAFF
SAVINGS AT 30 SELECTED TERMINALS
(MILLIONS 1975 $)

Year	Configuration 1	Configuration 2-5
1976	-	-
1977	-	-
1978	-	-
1979	-	-
1980	-	-
1981	$2.1	$2.1
1982	4.2	4.2
1983	6.4	6.4
1984	8.5	8.5
1985	10.6	10.6
1986	11.1	15.0
1987	11.6	19.4
1988	12.1	23.6
1989	12.6	28.3
1990	13.1	32.7
1991	13.4	33.2
1992	13.7	33.8
1993	14.0	34.3
1994	14.3	34.9
1995	14.6	35.4
1996	14.7	35.8
1997	14.9	36.3
1998	15.1	36.7
1999	15.2	37.1
2000	15.4	37.5
Total	$237.5	$506.1

5.0 Conclusions

Each of the five alternative configurations evaluated by the UG3RD systems cost-benefit analysis (see Table 2.1) will produce significant reductions in the air traffic control staff requirements. Reduced manpower requirements provide significant savings in personnel costs. Estimated savings for the period 1976 through 2000 are as follows:

Configuration 1	- $4.1 billion
Configurations 2 and 4	- $4.7 billion
Configurations 3 and 5	- $5.3 billion

The major portion of staff savings will result from reduced manpower requirements at en route centers. En route savings constitute 94 percent, 89 percent, and 90 percent of total staff savings for UG3RD Configuration 1, Configurations 2 and 4, and Configurations 3 and 5, respectively.

Specific features of UG3RD configurations contributing to staff savings consist of:

1. Automated data handling.
2. Metering and spacing.
3. Automated local flow control.
4. Conflict probe.
5. Control message automation.
6. DABS-IPC, when combined with the control by exception principal.

Most anticipated productivity increases are associated with improved ATC automation, but DABS/IPC will be required to facilitate adoption of the control-by-exception principal and gain associated staff savings.

Appendix A

Descriptions of Component Programs of the UG3RD

1. Discrete Address Beacon System (DABS) will improve the surveillance of airspace and will provide a high-capacity, ground-air-ground data link which is related to the implementation of many of the other features of the UG3RD. In its surveillance role, DABS provide greater accuracy and reliability and will have improved discrimination with respect to aircraft flying in close proximity with other aircraft. It is intended as an evolutionary technical improvement to today's Air Traffic Control Radar Beacon System (ATCRBS) and will be fully compatible with ATCRBS airborne transponders and ground-based interrogators.

2. Intermittent Positive Control (IPC) is a feature oriented toward improving safety of flight and may reduce the number of midair collisions between aircraft flying in mixed airspace (some aircraft IFR, some VFR). Pilot warning advisories and collision avoidance commands will be generated on the ground and transmitted via data link to appropriately equipped aircraft. As the name implies, the ATC system will intervene only when necessary so that maximum freedom of flight can be maintained to the degree consistent with the safety of other users of the airspace.

3. Flight Service Stations (FSS) will be automated and exploit the use of unattended pilot self-briefing terminals. The FSS network will be restructured to make improved services more readily available to the user and to achieve reductions in operating and maintenance costs per unit of service rendered. A number of satellite stations and a lesser number of hub processing facilities will be used to support the self-briefing terminals.

4. Upgraded Air Traffic Control Automation functions will, for the most part, be provided by additions or modifications to the computer programs of computers and displays installed at the enroute centers (ARTCC's), at terminal area control centers (TRACON's), and at the national level traffic management and flow control center at FAA Headquarters. Some of the new automation functions will make use of other UG3RD features and will rely heavily on the DABS data link for the exchange of ATC messages with aircraft. Specific functions to be developed include metering and spacing of aircraft in terminal areas, conflict prediction, and fail-safe capability.

5. Airport Surface Traffic Control (ASTC) will provide the tools necessary to ensure safe efficient movement of air traffic on the surface of the airport in the face of increasing traffic, more complex mazes of runways/taxiways, and trends toward operation during periods of lower visibility. Improved radar surveillance and rather simple stop-go and visual signals to the pilot are planned for early development. Automation of some of the control functions, and improved displays and facilities for the local controller and ground controller located in the tower cab, are planned for the future. These improvements may contribute to increased airport capacity, reduced delays, and the avoidance of collisions between aircraft and vehicular traffic on the airport surface.

6. Wake Vortex Avoidance System (WVAS) is to provide the basis for increased airport capacity and improved safety through the means of detecting and/or predicting the presence of high-energy wake vortices created by large heavy aircraft during low speed on final approach or departure. Reduced separation between aircraft on final approach is expected to be realized as a result of having knowledge as to the presence and location of such vortices in contrast to today's practice of using larger separation standards to assure safety because of lack of knowledge as to the presence or absence of dangerous wake turbulence.

7. Area Navigation (RNAV) can permit the establishment of direct routes between pre-selected fixed points rather than having to fly along selected radials from VOR/DME stations or to involve controllers in providing radar vector instruction. This should provide improved service to the user and may reduce his operating costs by providing more direct routing. It also is expected to improve efficiency of ATC operations in terminal areas, and possibly reduce controller workload and costs by relieving them of the need to provide radar vector commands.

8. Microwave Landing System (MLS) may be developed to satisfy the needs of both civil and military aviation. Various ground and airborne configurations will make it possible to select the minimum cost configurations best suited for particular needs. Site preparation costs will be significantly less than

for standard UHF/VHF ILS. Installations will be possible at difficult sites where ILS is not now practical. Improved performance will be available in the form of a multiple glide slope and curved approach capability which can be used to provide approach paths with minimum noise impact on areas surrounding the airport. Reduction in noise may also make it possible to resume use of certain runways where operations are precluded or restricted because of noise problems.

9. AEROSAT is a program aimed at exploring the use of satellites for improving oceanic ATC communications and providing surveillance information to reduce oceanic air separation standards and improve the management of oceanic air traffic. This program, which is being pursued jointly with ESRO and with Canada, will lead to the design of a future operational system and international agreement as to the standard operating porcedures to be followed in the use of such a system. The ultimate objective, which is beyond the scope of the current AEROSAT program, is to achieve an operational system in time to satisfy demands which cannot be met through the continued use and the greater efficiency of air operations through reduced separation standards offer the potential for reductions in costs over the long term.

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